AIR-LAID WEB WITH HOLLOW SYNTHETIC FIBERS

RELATED APPLICATION

This application is a continuation-in-part of U.S.S.N. 10/345,001 filed January 15, 2003 in the name of Mabrouk Ouederni, which was itself a continuation-in-part of U.S.S.N. 09/896,799 filed June 29, 2001.

BACKGROUND OF THE INVENTION

1) FIELD OF THE INVENTION

The present invention relates to a single layer air-laid composition useful as an absorbent core in diapers, incontinent pads, sanitary napkins and other absorbent pads needed for body fluids. In particular, the present invention comprises a composition of an absorbent comprising wood pulp and optionally a super absorbent polymer, a binder system, and up to 50% hollow synthetic fibers based on the total composition weight. The composition of the present invention has an improved loft, compression resistance and fluid intake rate superior to existing composites based on natural absorbents and non-hollow synthetic fibers.

Diapers, incontinent pads, sanitary napkins, and other absorbent pads used for uptaking bodily fluids generally consist of several layers. A hydrophilic top layer is generally employed for rapid uptake of any insulting fluid. This is often followed by a high lofted bulky layer. The bulky layer is not provided with any liquid absorbing capacity in itself, but rather serves to disperse the insulting liquid to a broader surface area of the next layer, the absorbent core. This engages a greater percentage of the absorbent located in the core, prevents gel blocking, and gives the absorbent core a greater liquid storage capacity. The bulky layer is often a hydrophobic composition, in order to prevent strikethrough and rewet. The absorbent core

functions as the final holding reservoir for the insulting liquid. It therefore contains any absorbent contained in the article, including any wood pulp or super absorbent polymer that may be employed. It is with this absorbent core that the present invention is concerned.

2) PRIOR ART

Disposable absorbent articles such as disposable diapers, have found much success in the marketplace, however, there is always a need to improve these products in terms of their low density, high loft, compression resistance, and fluid uptake rate. Prior to the present invention, it was known to form absorbent cores using dry-laid composites from wood pulp (and optionally up to about 25% super absorbent polymer, SAP), bicomponent fibers as a binder, and synthetic fibers for loft and compression resistance. This existing composition contained approximately 10% bicomponent fibers, about 10% polyester fibers, and approximately 80% wood pulp. This product had adequate loft, fluid intake rate, and good wet strength. Generally this product was created by forming a dry-laid web carded bicomponent fibers and synthetic fibers and then adding the wood pulp (and optionally the SAP) to the web. The dry-laid composite was then introduced into a heating zone, such that the lower melting material of the bicomponent fiber would melt and the molten lower melting material would run to the intersection where the fibers cross one another. Next, the composite was introduced into a cooling zone where the web was cooled, thus solidifying the molten lower melting material, thereby binding the mixture into a unitary web structure.

U.S. Patent 4,364,992 to Ito discloses a two layer absorbent article with SAP polymer. The first absorbent layer was preferably produced from a standard non-woven sheet made with polyester fibers and bicomponent binder fibers. It was critical that the basis weight of this layer should be 15 to 50 grams per square meter (gsm) and its density in the wet state, under a load of 35 grams per square centimeter, should be lower than 0.045 g/cm3, preferably lower than 0.03 g/cm3. In addition if large diameter fibers were used in this first layer, in order for the web to exhibit a certain springiness, the web could become stiff. Ito disclosed that 30–60% hollow fibers, with a fineness of 6 to 12 denier could be mixed in this first absorbent layer. The problem that Ito sought to solve was leakage due to an insufficient absorbing capacity in the first

absorbing layer. There is no teaching as to the use of hollow fibers in the second layer (the absorbent core).

U.S. Patent 6,368,990 to Jennergren et al discloses a nonwoven fabric of hollow polypropylene spunbond fibers or hollow polypropylene staple fibers. The hollow fibers do not increase absorbance, but only make the product lighter in weight and increase the bond strength. The fabric is a multilayer layer composition that can be used as a top sheet in a diaper, but it does not teach the use of hollow fibers in an absorbent core.

U.S. Patent 5, 041,104 to Seal discloses a fabric of absorbent and synthetic fibers that are bonded to one another using powder bonding. Later the fibers are subject to a heat oven where the bonding resin is liquefied again and the fibers are permitted to reloft themselves, and then they are cooled again to resolidify. The fibers are crimped. The fibers have a staple length of from 25 to 100 mm and are cardced in to a dry-laid nonwoven structure, not an air-laid non-woven.

U.S. Patent 6,046,377 to Huntoon et al discloses a disposable diaper having many layers such as a bodyside liner, an outer cover, and an absorbent layer. The absorbent layer has staple fiber which is wood pulp or synthetic fiber, but is not hollow fiber. Additionally, these staple fibers can be up to 15 cm in length. There is no disclosure with regard to air-laying short staple fibers.

U.S. Patent 5,023,131 to Kwok discloses thermofusible batts consisting of cotton fibers and a PET/PEI copolyester that is useful for fiberfill insulation, padding, resilient cushioning, and the like, with excellent washability. The fibers should have a length from 0.8 to 1.5 inches (20 – 38 mm). Consistent with its use, Kwok '131 does not teach the value of hollow fibers for improving loft, compression resistance or liquid acquisition rate. There is also no teaching of air forming with wood pulp, hollow and binder fibers.

U.S. Patent 5,989,688 to Barge discloses a first bulky layer composite nonwoven for the acquisition and distribution of fluids to an absorbent core. The disclosed composite does not

disclose an absorbent as part of its structure. It therefore does not disclose the unique features of the instant invention in which the absorbent is combined in a single layer web with a binder and hollow fibers. Additionally, the bulky layer of Barge is formed by a carding process. There is no teaching on the use of air forming with wood pulp, hollow and binder fibers.

It is an object of the present invention to improve upon the loft, compression resistance, and the fluid intake rate of an absorbent core. These features should be achieved without any loss of wet strength.

SUMMARY OF THE INVENTION

The present invention relates to an air-laid composition comprising absorbent, binder, and hollow synthetic fibers. If the binder system is based on binder fibers, it is desired to maintain the percentage of binder at about 10% by weight as it has been determined that this amount of binder is sufficient to adequately bind the web into a unitary structure. On the other hand, the hollow fiber can comprise from about 10% up to about 50% by weight of the composition. This means that the absorbent comprise from 40% to 80% by weight of the composition. Replacing the solid synthetic fibers with synthetic hollow fibers surprisingly increases the loft, and the fluid intake rate, as well as the compression resistance.

In the broadest sense, the present invention relates to a single layer air-laid composite of absorbent, a binder system, and hollow synthetic fibers.

Air-laid composites of the present invention provide good compression resistance, loft, and fluid intake increase as compared with a composite based on bicomponent fibers, wood pulp fibers, and solid synthetic fibers. To increase the absorbency of the web of the present invention, some of the wood pulp may be replaced with SAP.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The air-laid webs of the present invention are created by introducing the fibers into an air current, which uniformly mixes the fibers, and then deposits them on a screen surface.

The web of fibers can be bonded by mechanical, chemical or thermal means. Mechanical bonding uses entanglements introduced by needle punching or hydroentangling. If no other binder system is employed, the web comprises absorbent and hollow fibers. Generally, mechanical bonding is inadequate for most uses of the web of the present invention. Chemical bonding uses adhesives such as latex resins, or hot melt adhesives. These types of chemical bonding can coat the wood pulp fibers decreasing their absorbency. Thermal bonding utilizes low-melt binder fibers in an oven (hot air, radiant or microwave), or on heated calender roll(s), or by ultrasonic energy.

If the binder system and absorbent are in the form of fibers, these fibers can merely be added to the synthetic fibers when the air-laid webs are created according to the process described above. This has the added benefit that a screen conveyor belt can transport the mixed components to a heating zone, which causes the binder fiber to become molten, and then to a cooling zone where the molten binder resolidifies. The web now has sufficient rigid structure to be useful as a component of an absorbent pad.

Suitable absorbents are natural or synthetic absorbents. Synthetic absorbents are primarily known as super absorbent polymers (SAP). The absorbents comprise 40–80 % by weight of the absorbent core. Natural absorbents are hydrophilic materials such as cellulosic fibers, wood pulp fluff, cotton, cotton linters, and regenerated cellulose fibers such as rayon, or a mixture of these. Preferred is wood pulp fiber, which is both inexpensive and readily available.

Conventional natural absorbents do not absorb as much bodily fluid as when a portion of them has been replaced with synthetic fibers, and preferably polyester fibers, which provide loft to the composite. Providing loft to the composite exposes more surface area of the natural absorbents to the bodily fluids and thus the natural absorbents are much more efficient in

absorbing the bodily fluid, compared to absorbent cores having little or no loft, but more absorbent material.

Absorbent cores employing natural absorbents may not provide adequate fluid intake for all circumstances. Also natural absorbents are very bulky. Accordingly, many absorbent pads employ SAP in relatively low quantities because the cost of SAP is much higher than the cost of natural absorbents. Replacing some of the natural absorbents with SAP can reduce the overall bulk of the pad and/or provide superior fluid intake.

As used herein, the term "super absorbent polymer" or "SAP" refers to a water-swellable, generally water-insoluble material capable of absorbing at least about 10, desirably about 20, and preferably about 50 times or more its weight in water. The super absorbent polymer may be formed from organic material, which may include natural materials such as agar, pectin, and guar gum, as well as synthetic materials such as synthetic hydrogel polymers. Synthetic hydrogel polymers include, for example, carboxymethyl cellulose, alkali metal salts of polyacrylic acid, polyacrylamides, polyvinyl alcohol, ethylene maleic anhydride copolymers, polyvinyl ethers, hydroxypropyl cellulose, polyvinyl morpholinone, polymers and copolymers of vinyl sulfonic acid, polyacrylates, polyacrylamides, polyvinyl pyridine, and the like. Other suitable polymers include hydrolyzed acrylonitrile grafted starch, acrylic acid grafted starch, and isobutylene maleic anhydride copolymers and mixtures thereof. The hydrogel polymers are preferably lightly crosslinked to render the materials substantially water insoluble. Crosslinking may, for example, be by irradiation or covalent, ionic, van der Waals, or hydrogen bonding. Suitable materials are available from various commercial vendors such as the Dow Chemical Company, Allied Colloid, Inc., and Stockhausen, Inc. The super absorbent polymer may be in the form of particles, flakes, fibers, films or any of a number of suitable geometric forms.

The synthetic hollow fibers improve the loft of the composite compared to a composite having solid synthetic fibers. These fibers typically have a denier of about 2 to about 18. Generally, the fibers are between 3 and 20 mm in length and preferably from about 4 to 12 mm in length. Preferably all the fibers are hollow. However a portion of them can be replaced with any other solid polymeric fibers. The synthetic hollow fibers comprise 10–50 % by weight of the

web. The web composition (absorbent core) of the present invention has weights in the range of about 50 to about 500 grams per square meter (gsm).

The synthetic hollow fibers may be formed from any polymeric material capable of forming fibers which fibers can be formed into a fibrous web. Suitable polymeric material, from which the synthetic hollow polymeric fibers may be formed, include polyolefins, such as polyethylene, polypropylene, and the like; polyesters such as polyethylene terephthalate or polybutylene terephthalate, or copolyesters such as polyethylene terephthalate-isophthalate or polyethylene terephthalate-adipate and the like; polyamides such as nylon 6, nylon 6,6, poly (iminocarboxylpentamethylene) and the like; acrylics, as well as mixtures and copolymers thereof. Preferred is polyester fiber such as polyethylene terephthalate.

The synthetic hollow fibers may be formed by a conventional melt spinning, drawing, crimping and cutting process into short-cut fibers having a length, for example, from about 1 millimeter to about 20 millimeters. The synthetic polymeric fibers may suitably have a maximum cross-sectional dimension of from about 10 micrometers to about 50 micrometers as determined by microscopic measurement using an optical microscope and a calibrated stage micrometer or by measurement from Scanning Electron photomicrographs.

Binder fibers can be conventional low melt fibers or bicomponent fibers. Conventional low melt fibers can be polyolefins, for example, and in particular can be linear low-density polyethylene. Bicomponent fibers can be of the type in which the low melting point portion is adjacent to the high melting point portion such as a side-by-side configuration, or in a sheath-core configuration wherein the sheath is the lower melting component and the core is the higher melting component. In typical bicomponent fibers, the low melting component comprises 25–75% by weight, while the high melting component comprises 75–25% by weight. Many commercially available bicomponent fibers are about 50–50. When bicomponent fibers are used, the low melting portion should comprise about 10% by weight of the entire absorbent core, while the amount of synthetic fiber includes the high melting portion. The binders are thermally bonded by conventional means such as by using an oven (hot air, radiant or microwave), or calender roll(s), or by ultrasonic energy. It is contemplated that the web of the present invention

will comprise between 3 and 15 % by weight binder fiber, such as bicomponent fiber. This amount of binder fiber is deemed to be adequate to bind the web into a unitary structure. Preferably, about 10% by weight binder fiber or an equivalent amount of bicomponent low melt component (based on the weight of the web(absorbent core)) gives most satisfactory results.

Suitable bicomponent fibers have a denier of between about 2–18 and can comprise polyethylene/polypropylene; polyethylene/polyester (especially polyethylene terephthalate); polypropylene/polyester; copolyester/polyethylene terephthalate, such as polyethylene terephthalate-isophthalate/polyethylene terephthalate; nylon 6/nylon 6,6; and nylon 6/polyethylene terephthalate. Preferably polyethylene/polyester are used, especially grafted polyethylene/polyethylene terephthalate, such as linear low-density polyethylene/polyethylene terephthalate. Bicomponent fibers having a denier of between 2 and 6 are the preferred binder fiber.

The absorbent core may be formed by the air-laid processes previously mentioned. If binder fibers are employed, a screen conveyor belt conveys the web to a heated zone of sufficient temperature and having a sufficient residence time such that the low melting material of the binder fiber melts, flows to the intersection of a group of overlaid, contacting and intersecting fibers. Next, the web is transported on the conveyor belt to a cooling zone where all the molten material solidifies thus making the web structurally rigid. Thereafter, the absorbent core may be cut into various lengths and widths for the end use applications, namely, fenestration drapes, dental bibs, eye pads, diapers, incontinent pads, sanitary napkins, wet wipes, and wound dressing pads.

TEST PROCEDURES

The properties of the polyester fibers and webs were measured according to the following procedures.

Loft

The loft under various loads was measured with a tensile tester having a pressure foot with an area of 50 sq. in. Crosshead speed was set at 24 in./minute.

Four non-woven sheets were stacked on each other and placed on the crosshead table. The crosshead was raised until the pressure foot comes in contact with the stack of non-woven sheets; the thickness was measured and reported as the initial loft (L_i inch). The crosshead was raised, and stopped for 30 seconds, at each of the following loads, 0.5, 2, 4, 10, 15, 25 and 50 lb. and the thickness measured at each load. After 5 minutes under a load of 50 lb., the crosshead was then lowered until the pressure foot is completely clear from the non-woven stack. After allowing the sample to relax for 5 minutes, the crosshead was raised until a load of 0.5 lb. was indicated, and the thickness measured (L_1 in.). The thickness under the initial load of 0.5 lb. (L_0 in.) is used in the calculation of % recovery, rather than the initial loft (L_i), to eliminate any variations in thickness due to the stacking of the sheets.

The percent recovery is

$$(L_1/L_0) \times 100$$

Web Strength

The wet and dry strength of the web was measured according to TAPPI test methods T 456 om-87 and T 494 om-88 respectively. The wet strength is measured after an immersion time of 15 sec.

Liquid Acquisition Test

An 8-centimeter (cm) diameter sample is supported at the bottom of a 8 cm. diameter cylinder, such that the liquid that flows through the sample is collected on one balance, and the liquid that overflows from the top of the sample is collected on another balance. 100 ml of a

0.9% saline solution is poured onto the surface of the sample at a nominal flow rate of 7 ml/sec. The weight of the liquid that leaks and overflows is recorded at 2 second intervals.

Acquisition Rate

A 6 in. (15.2 cm) square of the web is placed horizontally between 2 clamps. 100 ml of water is poured onto the center of the sample at a rate of 20 ml/sec. The time (t in sec.), from the completion of the pouring, for the water to disappear from the surface of the web is recorded. The acquisition rate (AR, ml/sec.) is:

$$AR = 100/t$$

EXAMPLES

All webs for these examples were prepared with the same basis weight of 263 gsm, and all the polyester fibers were of 6 mm length. The bicomponent fiber (10% of the web composition) was KoSa Type 255, 3 den (denier), 6 mm length.

Example 1

In Example 1, four different web compositions were prepared by means of the air-laid procedure described previously, in which the amount of polyester fiber varied from 0 to 40% by weight of the total web and varying the denier of polyester fiber and its cross-section (solid or hollow).

Where the data indicates that there is no polyester means that the composition of the web comprised 10% bicomponent fibers and 90% wood pulp fibers. The results are set forth in Table 1, which shows the improved initial loft using a hollow fiber at a 40% level.

Table 1

Initial loft (no loading), in.				
% PET	0	10	20	40
Solid 3 den	1.4	1.6	-	-
Solid 6 den	1.4	1.6	1.6	1.7
Hollow 6 den	1.4	1.6	1.8	2.3
Solid 15 den	1.4	1.6	-	-

Table 2 shows the improvement in loft under compression with all webs containing additional polyester fibers at the 10% loading.

Table 2

Loft under compression, in. (10% PET)							
Load, lb	0	0.5	2	4	10	15	25
No PET	1.4	1.3	1.2	1.1	0.9	0.7	0.5
Solid 3 den	1.6	1.5	1.3	1.2	1	0.9	0.8
Solid 6 den	1.6	1.5	1.3	1.2	1	0.95	0.85
Solid 15 den	1.6	1.5	1.4	1.3	1.1	1	0.9
Hollow 6 den	1.6	1.5	1.3	1.2	1	0.9	0.8

Tables 3 and 4 show the improvement in loft under compression at a 20% and 40% loading of a hollow 6 denier fiber compared to a 6 denier solid fiber.

Table 3

Loft under compression, in. (20% PET - hollow effect)							
Load, lb	0	0.5	2	4	10	15	25
No PET	1.4	1.3	1.2	1.1	0.9	0.7	0.5

Solid 6 den	1.6	1.4	1.2	1.1	0.9	0.8	0.7
Hollow 6 den	1.8	1.7	1.5	1.4	1.1	1	0.8

Table 4

Loft under compression, in. (40% PET - hollow effect)							
Load, lb	0	0.5	2	4	10	15	25
No PET	1.4	1.3	1.2	1.1	0.9	0.7	0.5
Solid 6 den	1.7	1.6	1.4	1.3	1.1	1	0.85
Hollow 6 den	2.3	2	1.8	1.6	1.4	1.2	1.1

Tables 5 and 6 illustrate the better recovery from compression with higher denier fibers, and with hollow fibers at the same denier.

Table 5

% Recovery	
No PET	81
10% solid 3 den	83
10% solid 15 den	88

Table 6

% Recovery	
No PET	81
40% solid 6 den	87
40% hollow 6 den	89

Example 2

The web wet/dry strength ratio in the machine direction (MD) and cross direction (CD) of various webs was compared. The first web has no synthetic fiber (no PET), the second and third webs have solid fiber and the last web has hollow fiber. The solid and hollow fiber webs contained 10% bicomponent, 80% wood pulp and 10% polyester (of either 3 denier solid, 15 denier solid, or 6 denier hollow). The results are set forth in Table 7.

Table 7

Wet/Dry Strength (%)		
	MD wet/MD dry	MD wet/CD dry
No PET	0.40	0.42
10% solid 3 den	0.60	0.62
10% solid 15 den	0.59	0.61
10% hollow 6 den	0.60	0.63

The results show that webs having synthetic fibers are an improvement over the web with no PET, while the web with hollow fiber had results comparable to solid fiber webs.

Example 3

The liquid acquisition test compared 6 den solid PET with 6 den hollow PET. The results are set forth below in Tables 9 and 10, and illustrate that the hollow fiber prevented any overflow. The most desirable behavior is to have instant penetration – no overflow and little or no leakage. Failing that, one wants as little overflow as possible, and to have the onset of overflow delayed as long as possible.

Table 9

Overflow, ml										
Time, second	0	2	4	6	8	10	12	14	16	18
Solid PET	0	0	0	0	6	13	21	29	34	34
Hollow PET	0	0	0	0	0	0	0	0	0	0

As the results show, the hollow fiber web had no overflow even after 18 seconds, indicating instant liquid penetration. This is a very desirable result for disposable diapers, for example.

Table 10

Leakage, ml										
Time, second	0	2	4	6	8	10	12	14	16	18
Solid PET	0	0	0	0	3	10	17	24	30	34
Hollow PET	0	0	0	0	2	13	26	40	52	53

Comparing the total of Overflow and Leakage, the hollow fiber webs are superior to solid fiber webs.

Table 11 shows the improved acquisition rate of these webs. The higher the acquisition rate the faster the web permits liquid to flow through it. This means that bodily fluids do not remain in contact with the skin for a long period of time, another desirable feature for disposable diapers and incontinent pads. Hollow fiber webs have a rate double that of solid fiber webs.

Table 11

Acquisition Rate (ml/sec)	
No PET	2
Solid PET	3
Hollow PET	7

Thus it is apparent that there has been provided, in accordance with the invention, a single layer air-laid composition that fully satisfies the objects, aims, and advantages set forth above. While the invention has been described in conjunction with specific embodiments thereof, it is evident that many alternatives, modifications, and variations would be apparent to those skilled in the art in light of the foregoing description. Accordingly, it is intended to embrace all such alternatives, modifications, and variations as fall within the spirit and broad scope of the invention.